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PRECIPITATION CLIMATOLOGY OF THE TEHRAN AREA

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SUMMARY

The rainfall climatology of the Tehran area, based on precipitation data for the period from 1894 to 1974, was studied. The probabilities of occurrences of selected amounts of annual and monthly precipitation were estimated and presented, using the Gaussian and gamma distributions respectively. The secular trend of annual precipitation was checked. A series of monthly, seasonal and annual isopleth maps concerning precipitation and the distribution of the numbers of rainy days were analysed for the five-year period beginning in 1969. No notable tendency was found for more frequent occurrences of rainy days or for maximum precipitation over the city. On the contrary, the existence of a peculiar phenomenon of the 'jump-over' of rainy areas over the city seems to be confirmed. Evidence of decreases induced by urbanization was found in the number of weakly rainy days for the city centre of Tehran and is discussed.

1. INTRODUCTION

This work has been undertaken with the following two goals in mind:

(a) A statistical investigation of the monthly and annual precipitation data for Tehran.

(b) A mesoclimatological study of daily, monthly, seasonal and annual precipitation within a radius of 30 to 60 km of the city's centre, in order to establish whether any unusual values potentially related to urban effects appeared to be present.

For the first part only monthly and annual precipitation data for Tehran from 1894 to 1974 were used. Observations for Mehrabad Airport made by the Iranian Meteorological Organization date back only to 1944. Before this date the data were obtained from the British Embassy and from *World Weather Records*. The missing months, with interrupted records, which were very few, were reconstructed by using mean monthly values.

According to Hashemi (1969) the rainfall measurements of Mehrabad Airport and the British Embassy are considered as homogeneous for the purpose of climatological study, and all calculations based on these records are performed without regard to the precise station to which the data refer.

For mesoclimatological study of the Tehran area daily precipitations of selected urban and suburban meteorological stations during the period 1969–73 were used. It seems here that the homogeneity of data for all stations will overcome the shortness of the periods. The locations of these stations are shown in Figure 1.

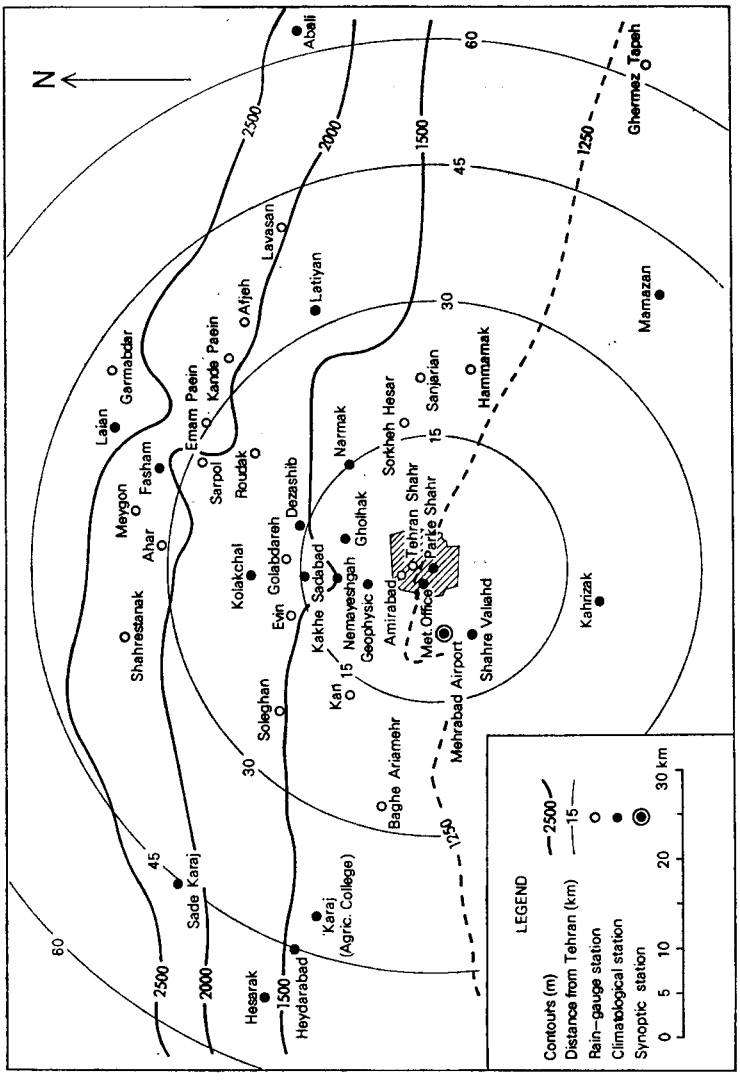

FIGURE 1—LOCATION OF STATIONS USED IN THIS STUDY

A review of research works reveals that, as yet, no study has been performed concerning the effect of Tehran city on precipitation. The lack of densely spaced precipitation stations with good historical records and the difficulties associated with delineating orographic effects (which are very important in this area) are the primary reasons for so little research on urban effects. But for some other regions of the world the subject has been studied by various authors: Changnon, 1968; Woollum, 1968; Sekiguti and Tamiya, 1969; Huff and Changnon, 1973, etc.

2. Precipitation climatology of Tehran

Monthly precipitation analysis

Table I shows the mean monthly precipitation of Tehran for the period 1894–1974. The annual regime of rainfall is a semi-mediterranean type which is characterized by a dry period (June–October) and a principal maximum in January or March. Forty-nine per cent of the precipitation occurs during the winter-time (January, February and March).

TABLE I—MONTHLY MEAN VALUES OF PRECIPITATION IN MILLIMETRES FOR TEHRAN (1894–1974)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
39·6	34·7	40·5	31·9	15·2	2·8	2·9	1·6	1·4	7·7	24·2	31·7

In order to obtain further information about the monthly precipitation of Tehran the gamma distribution was used. The probability of receiving a monthly value of precipitation equal to or greater than a selected value of X millimetres in this model is

$$P(x \geqslant X) = \frac{m}{(m+n)\beta^{\alpha+1}\Gamma(\alpha+1)} \int_0^X x^{\alpha} e^{-x/\beta}\, dx, \quad \ldots \quad (1)$$

where

n is the number of wet months
m is the number of dry months
$\Gamma(\alpha + 1) = \alpha!$ is the ordinary gamma function.

The parameters α and β may be estimated as follows.
Let the rainfall of the ith wet month be x_i.
Define the arithmetic mean of all the x_i by

$$M(x) \equiv (x_1 + x_2 + \ldots + x_n)/n, \quad \ldots \quad (2a)$$

their geometric mean by

$$G(x) \equiv (x_1 x_2 \ldots x_n)^{1/n}, \quad \ldots \quad (2b)$$

and a quantity A by

$$A \equiv \ln \{M(x)/G(x)\}. \ldots \quad (2c)$$

Then

$$\alpha = A^{-1}\{0{\cdot}25 + 0{\cdot}144(3 + 4A)^{\frac{1}{2}}\} - 1 \quad \ldots \quad (3)$$

$$\beta = M(x)/(1 + \alpha). \ldots \quad (4)$$

Values of α and β derived in this way are good approximations to their maximum likelihood estimates (Thom, 1958).

The observed and calculated frequencies were subjected to the chi-square test for January, April, July and November only. No significant differences were found. These results were accordingly generalized, and the model was used for all 12 months. The values of X corresponding to the various selected constant probability levels were calculated for each month by using Pearson's tables (1946), and the results are presented in Table II, which gives detailed information about the monthly precipitation of Tehran.

TABLE II—CALCULATED AMOUNTS OF MONTHLY PRECIPITATION WHICH HAVE A GIVEN PROBABILITY OF BEING EXCEEDED

Probability	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						millimetres						
0·05	100·4	94·5	91·8	84·9	86·6	10·0	4·5	9·8	8·1	28·6	70·0	103·1
0·10	79·9	75·0	73·0	66·5	36·5	7·5	2·5	5·7	5·2	20·0	59·8	80·4
0·20	57·5	56·0	55·0	49·5	27·0	4·2	0·0	2·5	1·0	13·2	36·2	59·5
0·40	36·7	32·5	35·5	35·5	16·5	0·0	0·0	0·0	0·0	4·5	21·9	35·4
0·50	30·0	24·5	27·0	27·0	12·5	0·0	0·0	0·0	0·0	1·5	15·5	27·5
0·60	22·5	18·0	23·5	21·5	9·1	0·0	0·0	0·0	0·0	0·0	11·7	21·3
0·80	11·5	9·0	12·5	12·5	3·0	0·0	0·0	0·0	0·0	0·0	3·1	10·4
0·90	6·0	4·5	7·5	6·5	1·5	0·0	0·0	0·0	0·0	0·0	0·0	5·5
0·95	3·5	1·7	5·5	2·5	1·0	0·0	0·0	0·0	0·0	0·0	0·0	3·1

Annual precipitation analysis

The annual precipitation of Tehran varies between 91 and 560 mm but the probabilities of obtaining these extreme values are very low.

The following are some statistical parameters of the annual precipitation of Tehran.

Mean: $x = 234{\cdot}2$ mm.
Standard deviation: $S_x = 88{\cdot}7$ mm.
Coefficient of variation CV: $= 100\, S_x/x = 37{\cdot}9$.

The frequency distribution of annual precipitation during the period under study has been examined. The unimodal aspects of the frequency histogram (which is not shown here) suggest that it could be successfully fitted to the Gaussian distribution. The calculated and theoretical frequencies were subjected to the chi-square test. The computed chi-square with four degrees of freedom was 8·13 and the tabulated chi-square with the same number of degrees of freedom at the 5 per cent level was 9·49. It was therefore concluded that the differences between theoretical and observed frequencies were not significant.

The probabilities (in per cent) of receiving amounts of annual rainfall equal to or less than (or equal to or more than) X mm of rain were calculated respectively from the following equations:

$$P(x \leqslant X) = 0{\cdot}4499 \int_{-\infty}^{X} \exp\{-6{\cdot}35 \times 10^{-5}(x - 234{\cdot}2)^2\}\, dx \quad . . \qquad (5)$$

$$P(x \geqslant X) = 0{\cdot}4499 \int_{X}^{+\infty} \exp\{-6{\cdot}35 \times 10^{-5}(x - 234{\cdot}2)^2\}\, dx \ldots \quad (6)$$

The results of these calculations are presented in Figure 2.

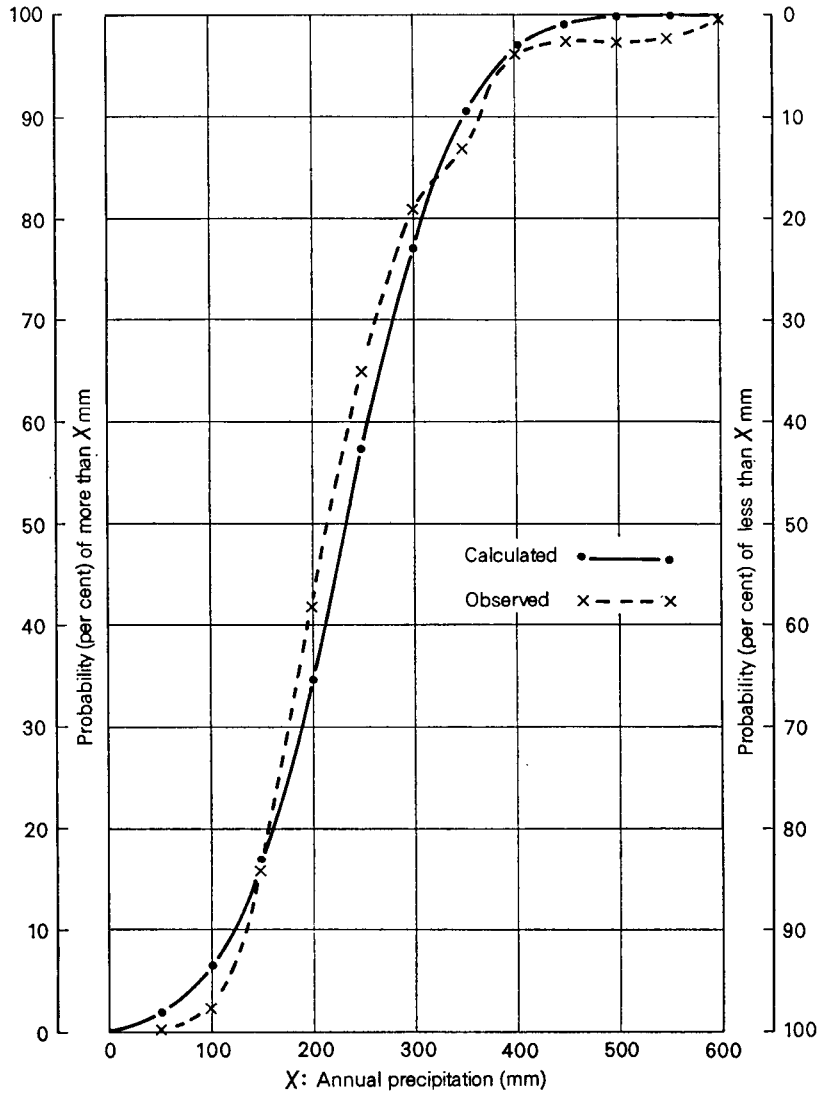

FIGURE 2—CUMULATIVE PROBABILITIES OF ANNUAL PRECIPITATION OF TEHRAN (1894–1974)

To gain further insight into year-to-year variation of annual rainfall the time-series of data were plotted as in Figure 3. To reduce the amount of variation present in the set of annual precipitation data and estimate the trend the moving averages of order 15 years were calculated and attributed to the mid year of each of the 15-year periods and plotted in Figure 3. This figure shows an increase of annual rainfall during the period 1916–28, and a relative decrease from 1920 to 1960, followed by a slight increase up to 1974, with, however, some moderate oscillations.

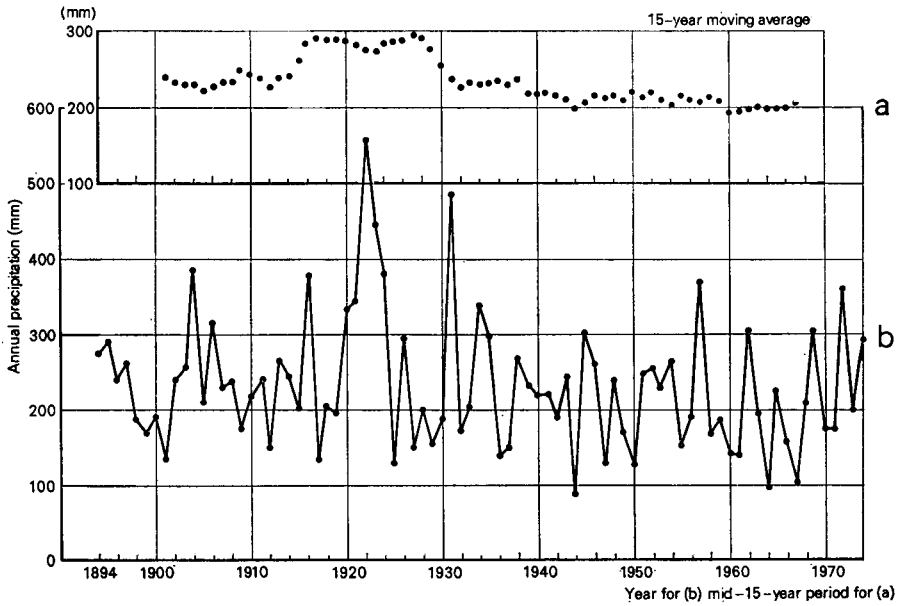

FIGURE 3—ANNUAL PRECIPITATION AND SECULAR TREND

3. Precipitation climatology of the Tehran area

The basic precipitation parameters employed in this part are the mean annual, seasonal and monthly values of (a) the usual expression for average rainfall in millimetres, (b) the number of rainy days with daily precipitation equal to or more than 0·1 mm and (c) the number of rainy days with daily precipitation equal to or more than 1 mm.

To calculate these parameters the daily values of precipitation for urban and suburban stations marked in Figure 1 for the five years starting in 1969 were checked statistically. Data for some stations were omitted because of important shortcomings in the records, and the short, interrupted records of some other stations were constructed by using the linear regression method. The records of 14 stations were completed and they served as principal points for study.

Finally the annual, seasonal and monthly distribution maps of the above-mentioned three parameters were drawn and compared. The analysis was therefore based on a total of 42 maps.

Major findings

In the northern part of the Tehran area the amount of precipitation increases with altitude and the orographic effects could be clearly seen during almost all periods. The values of increasing gradient have been reported by Khalili (1972). But in many cases no notable tendency was found for higher values of precipitation over the city in comparison with the rural areas to the east, south and west which have approximately the same elevation. Contrary to expectation, the existence of (a) a cell of minimum precipitation over the city which extends between Parke Shahr and Kan, and (b) a lower amount of precipitation over the city, seems to be confirmed. However, the probability of both of the above-mentioned phenomena is 53 per cent. Figure 4 shows the annual average rainfall pattern of the Tehran area.

The frequency distribution maps of the average number of rainy days (daily precipitation $\geqslant 0{\cdot}1$ mm*) demonstrate a minimum number of rainy days over or north-east of the city during almost all periods of the year. For example, data from the period under study on the frequency of rainy days showed that the rural stations averaged 17 more measurably rainy days than the urban stations' average of 43 days. The difference is significant at the 5 per cent level. Figures 5 and 6 illustrate two typical examples of the mean annual and seasonal frequency patterns of the number of rainy days.

A similar study was undertaken of the number of moderately rainy days (daily precipitation $\geqslant 1$ mm*). The moderately rainy day frequencies seem to be higher during the cold period and lower during the rest of the year; some isopleth maps, however, showed a reverse result. The average number of moderately rainy days was 35 a year downtown and 40 a year in the surrounding stations (Figure 7), but the difference is not so significant as for the days with the lower rainfall.

A comparison of mean monthly precipitation parameters, carried out between Parke Shahr situated downtown and Mehrabad Airport station, which is located 7 km west of the city centre and at an equal elevation, confirmed the previous results (Figure 8a–c) especially the lower mean values of the number of rainy days in Parke Shahr during almost all months which seem to be an effect of urbanization.

Generally, the spatial and temporal variation of precipitation amounts shows a greater similarity to the variation in the number of moderately rainy days than to the variation in the number of rainy days.

Furthermore, a comparison was made of the monthly values of precipitation amount, number of rainy days and number of moderately rainy days for both the above-mentioned stations. The absolute and relative frequencies of months with positive, negative and zero differences are presented in Table III. This table reveals a highly significant predominance of the negative difference frequencies for the monthly number of rainy days and supports, once more, the hypothesis of decreases produced by urbanization in the number of light rains. The negative frequencies are also moderately higher for both the other parameters, but not to a significant extent. Similar results were also reported for Japanese cities by Sekiguti (1970).

* These are called 'rain-days' and 'wet days' by the United Kingdom Meteorological Office (Editor).

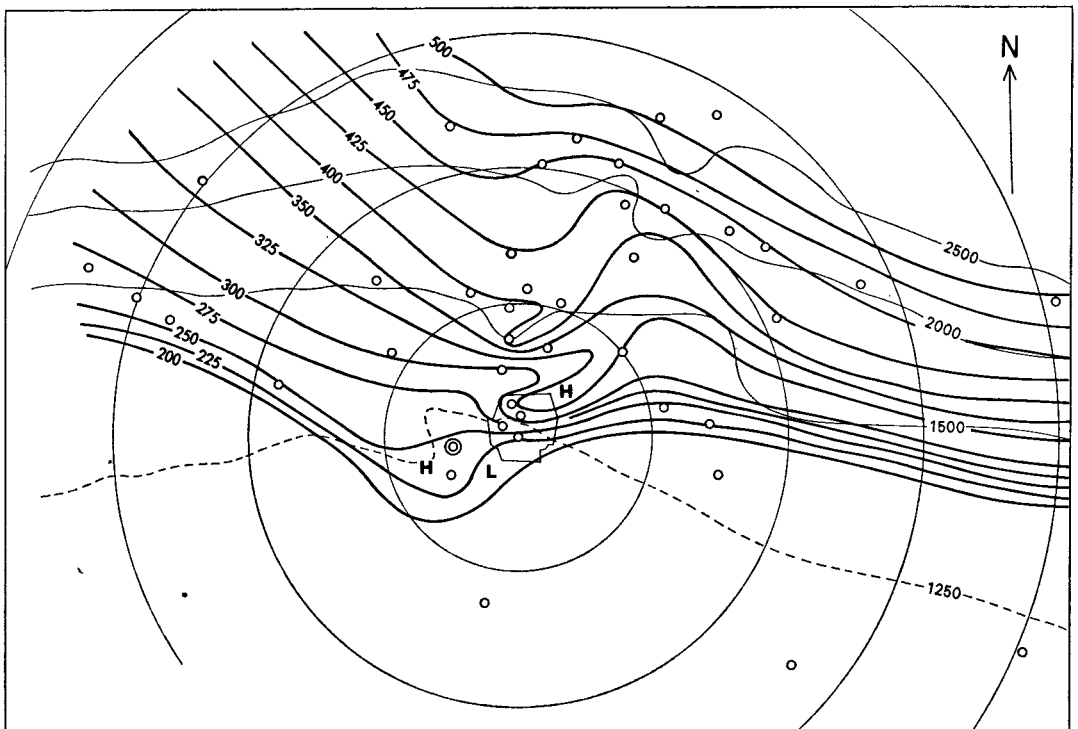

FIGURE 4—ANNUAL PRECIPITATION PATTERN IN MILLIMETRES OF THE TEHRAN AREA (1969–73)

The isopleth corresponding to 375 mm was omitted from the original diagram; the author has confirmed that the printed isopleths are correctly numbered.

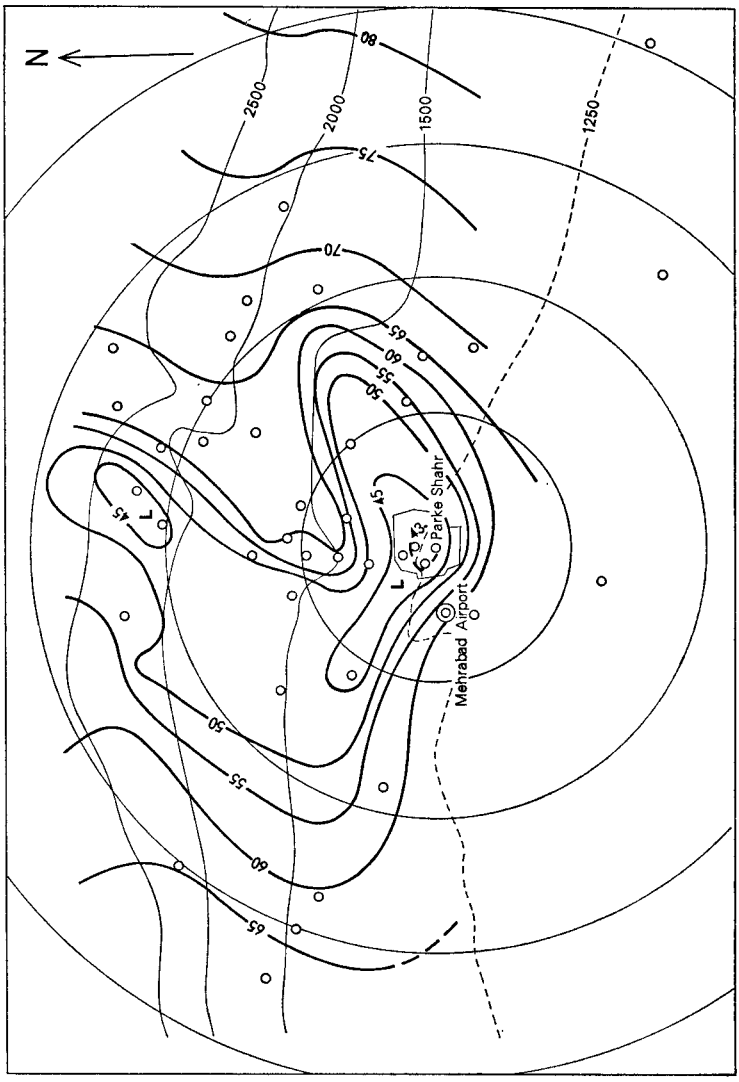

FIGURE 5—AVERAGE ANNUAL NUMBER OF RAINY DAYS ($\geqslant$0·1 mm) IN THE TEHRAN AREA (1969–73)

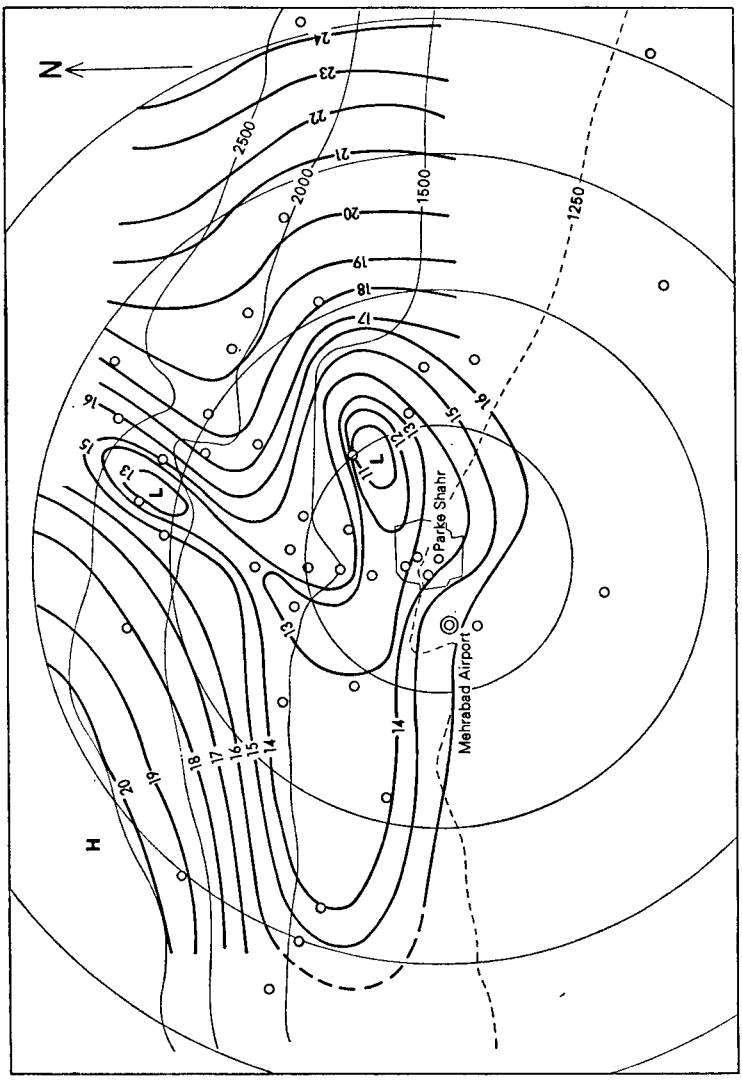

FIGURE 6—AVERAGE SEASONAL NUMBER OF RAINY DAYS (OCTOBER, NOVEMBER AND DECEMBER) IN THE TEHRAN AREA (1969–73)

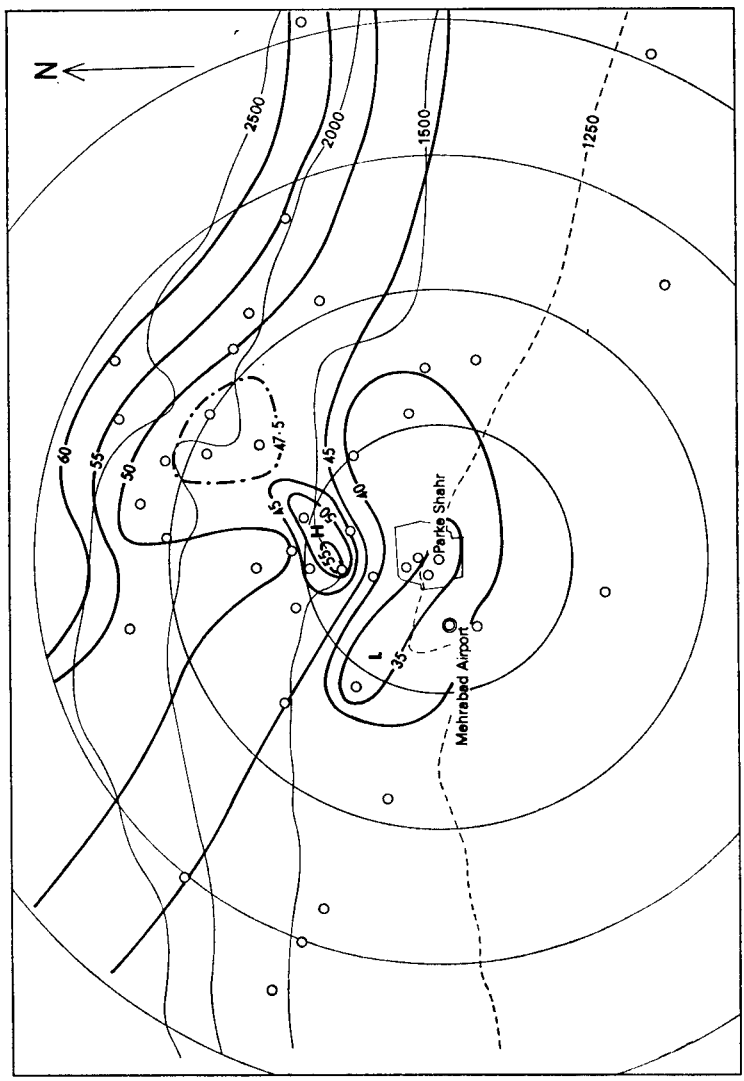

FIGURE 7—AVERAGE ANNUAL NUMBER OF MODERATELY RAINY DAYS WITH DAILY PRECIPITATION EQUAL TO OR MORE THAN 1 mm (1969–73)

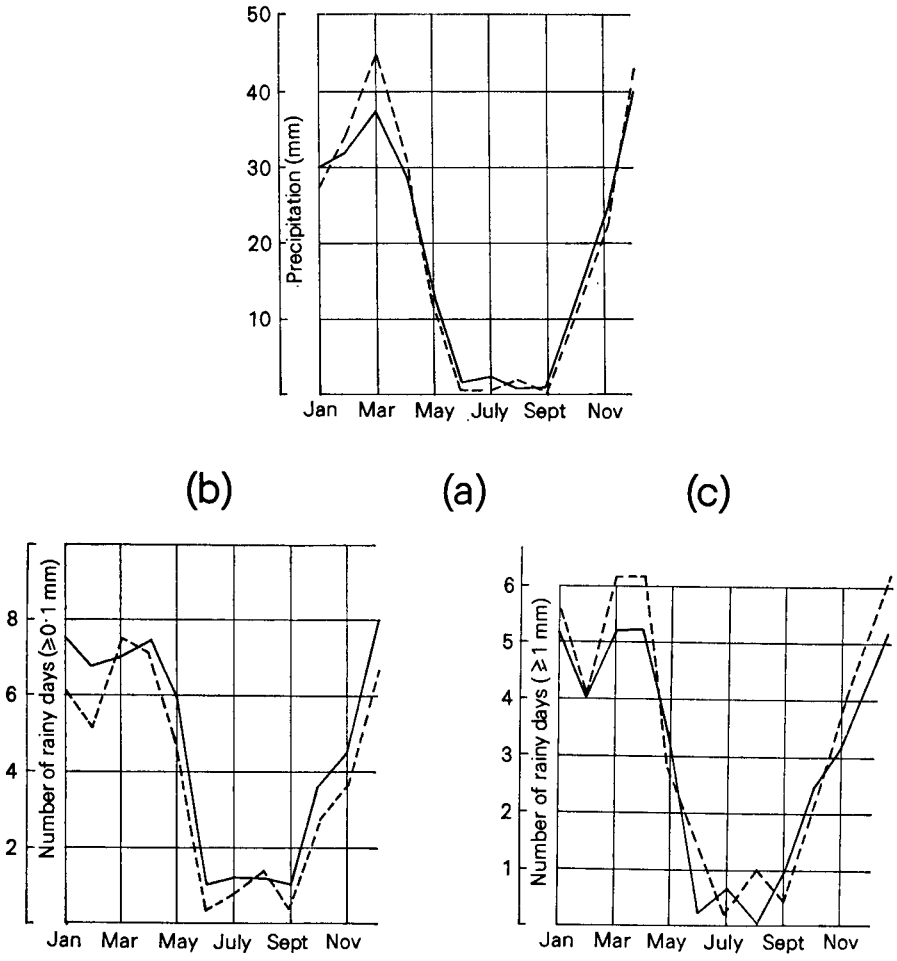

FIGURE 8—MONTHLY MEAN VARIATION OF PRECIPITATION AMOUNT, NUMBER OF RAINY DAYS AND NUMBER OF MODERATELY RAINY DAYS IN DOWNTOWN AND RURAL TEHRAN

(a) Precipitation amount

(b) Number of rainy days (≥0·1 mm)

(c) Number of moderately rainy days (≥1 mm)

——— Parke Shahr (downtown)

– – – Mehrabad Airport (rural)

4. Conclusions and discussions

This study provided evidence of the less frequent occurrence of the number of rainy days with daily precipitation equal to or more than 0·1 mm in the downtown section of Tehran during almost all months. The mean decrease in

TABLE III—COMPARATIVE FREQUENCY DISTRIBUTIONS (NUMBER OF MONTHS) OF THE PRECIPITATION PARAMETERS AT PARKE SHAHR (CITY) AND MEHRABAD AIRPORT (SUBURB) IN THE PERIOD FROM 1969 TO 1973

	City < Suburb	City > Suburb	City = Suburb
	−	+	o
Amount of precipitation	28 (47%)	22 (37%)	10 (16%)
Number of rainy days ≥ 0·1 mm	30 (50%)	13 (22%)	17 (28%)
Number of moderately rainy days ≥ 1 mm	17 (28%)	16 (27%)	27 (45%)

the number of rainy days was about 17 days a year (19 per cent) which was found to be statistically significant. The above-mentioned decrease occurred mostly during the cold period of the year. This result is not in agreement with those found in American and European studies, which have shown an increase of rainy days over cities.

As far as the annual mean values are concerned, the study provided little evidence of urban decrease effects on precipitation amounts as well as on the number of moderately rainy days over the city. On the contrary, some low monthly increases were observed for both the above-mentioned parameters, and these increases occurred mostly during the cold period of the year. It seems here that the annual and monthly values of precipitation are not related to the number of rainy days but rather closely related to the number of moderately rainy days. The spatial and temporal distributions of precipitation parameters confirmed the above-mentioned discovery. In conclusion, important decreases observed in the number of rainy days, over the downtown area, are not due to daily moderate and excessive rainfall but especially due to the number of days with light rain (between 0·1 and 1 mm rainfall a day).

By compiling the above-mentioned findings, we could offer the following hypothesis for explaining the plausible town-produced decreases in the number of light rains:

'The climate of Tehran is dry, and the relative humidity is generally low there. That is why the probable concentration of condensation and freezing nuclei over urban areas is not capable of producing some detectable changes in precipitation amounts.'

On the other hand, the urban thermal effects and the existence of the heat island over the city during the whole year have been pointed out as a primary result of a research project undertaken by the Iranian Meteorological Organization. Although the atmospheric instability due to this heat island is not able to produce the intense ascending air movement and consequently to intensify cloud formation because of air dryness, it is capable of evaporating the smaller raindrops suspended in the atmosphere and thus reducing the number of rainy days over the urban area of Tehran. The installation of a densely spaced meteorological station network is required to define more precisely the various urban effects on precipitation in Tehran.

ACKNOWLEDGEMENT

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551.524.36:551.589.6(420 + 429)

THE FIRST COLD SNAP OF AUTUMN

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SUMMARY

The first cold snap (as defined) in autumn has a mean date for most places near sea level in England and Wales in the first 10 days of November. The distribution about the mean date is in many places bimodal with one mode around the end of October and the second some 10 to 15 days later. At most places, 90 per cent of occasions lie within ±15 days of the mean. At stations with a long record the mean date for the 50 years 1921 to 1970 is some 2 to 3 days later than the mean date for the 50 years 1871–1920. Early dates are brought about by a northerly plunge over the United Kingdom, but later dates arise from a cold easterly airstream. On any occasion the first cold snap advances in a series of surges and averaged over many years, the mean date with increasing altitude is progressively earlier and amounts to one day for every 17½ metres of increased altitude.

Maps of the mean, earliest and latest dates (reduced to sea level by applying the correction) are shown. From them, the mean dates can be deduced for any place.

INTRODUCTION

In examining the structure of a forecast for the autumn season, it was considered that it would be useful to forecast the first cold snap of autumn since this could affect the milk yield of dairy herds. Also such a cold snap would be of interest to fuel and power suppliers since it would be related to a rapid increase in demand.

Definition

The date of the first cold snap at a place is defined as the second day of two consecutive days on both of which the day maximum screen temperature fails to exceed 9°C (48°F). This definition approximates to the type of weather occurring when dairy cattle, left out in the fields, have been known to suffer a loss of milk yield (L. P. Smith, private communication).

FREQUENCY DISTRIBUTION OF THE FIRST COLD SNAP BY PENTADS

The daily observed maximum screen temperatures for the places given in Figure 1, from the commencement of record (*c.* A.D. 1870) were examined and

FIGURE 1—LOCATION OF STATIONS USED IN THE INVESTIGATION

the annual dates of the first cold snap, determined according to the definition, were classified in groups of 5 days (pentads). Table I gives the distribution for a number of places in England. The range covered is about 11 to 14 pentads, i.e. a period of about two months, from the second week in October to the second week in December. At some of the stations in the table the distribution is bimodal with one maximum at the end of October (pentads 60 or 61) and a second maximum about 15 days later. An examination of all the stations used showed that for 70 per cent of them (28 out of 40) the distribution was bimodal. All but Plymouth, Penzance, Scilly and Haverfordwest had the first maximum in pentad 60 or 61. At all places except Southampton the second maximum was 10 to 15 days after the first. The places which did not show a bimodal distribution were all in the eastern half of England.

Secular change

Figure 2 gives the 10-year (running) means of the date of the first cold snap for Oxford from 1862, and Durham from 1881. The two graphs are similar with minima around 1896, 1927 and 1955, and maxima around 1907, 1945 and 1965, with a range of about 15 days. The fluctuations appear to have a periodicity of just under 30 years but an apparent periodicity of between 20 and 30 years is to be expected when 10-year moving averages are used (see Brooks and Carruthers, 1953). It is not proposed to make a statistical investigation into the reality or otherwise of this periodicity but merely to point out that fluctuations do occur. The fluctuations are caused by changes in the atmospheric circulation and Figures 3 to 5 give the circulation departures for a 10-year period when the mean date was early and for one when it was late. Figure 3 gives the mean pressure departure for October for the 10 years 1887 to 1896 from the mean for the period 1873–1968. The anomalous northerly gradient brought cold air from the north and hence increased the chance of two days with maxima $\leqslant 9°C$. Figures 4 and 5 give the mean pressure departure for October and November respectively for the 10 years 1956 to 1965. By contrast, October for these 10 years shows a negative anomaly south-east of Greenland and a positive anomaly over central Europe. The anomalous south-west flow over and to the north of Scotland indicates a decreased frequency of northerly winds. November for the 10 years shows anomalous high pressure from north Norway to Greenland. Continental air from the east brought late cold snaps.

Table II gives the mean date for a number of places with long records for the period from commencement of record to 1920 and for the period 1921–70. The average date for the second period is 2 to 3 days later than for the first.

At Oxford all the 10-year means before 1901 are earlier than 5 November. After 1901 only the periods ending in 1926–28 and 1950–59 have means earlier than 5 November. The mean for the period 1853 to 1900 is 2 November and for the period 1901–70 the mean date is 8 November.

These figures are consistent with the general warming of the climate in central England noted by the author (1972) for the months October to March. The fall of mean temperature from October to November for central England is about 3·5 K, i.e. about 0·12 K per day. The rise in mean October temperature from the period 1871–1920 to the period 1921–70 is about 0·75 K and for November about 0·25 K, giving an average change of about 0·35 K for the end of the first week of November and hence a delay of some 3 days in the average onset of the first cold snap.

TABLE I—FREQUENCY DISTRIBUTION OF FIRST COLD SNAP OF AUTUMN BY PENTADS

	No. of years	Pentad number																		Average date
			54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	
			Sept.		October						November						December				
		from	23	28	3	8	13	18	23	28	2	7	12	17	22	27	2	7	12	17	
		to	27	2	7	12	17	22	27	1	6	11	16	21	26	1	6	11	16	21	
Oxford	102		—	—	—	1	2	6	11	17	16	14	18	9	4	2	—	1	—	1	6 Nov.
Cambridge	98		—	—	—	1	1	5	13	15	16	15	14	11	6	—	1	—	—	—	6 Nov.
Southampton	116		—	—	—	—	—	3	4	15	12	18	18	23	9	7	1	5	—	1	13 Nov.
Ross-on-Wye	91		—	—	—	1	—	6	15	14	14	15	13	10	1	1	1	—	—	—	5 Nov.
Southport	79		—	1	—	2	1	3	14	8	12	14	12	7	3	—	—	2	—	—	6 Nov.
York	93		—	—	—	2	1	11	14	14	16	17	12	4	1	—	—	1	—	—	3 Nov.
Durham	99		1	—	2	3	6	14	20	16	16	11	5	5	—	—	—	—	—	—	29 Oct.

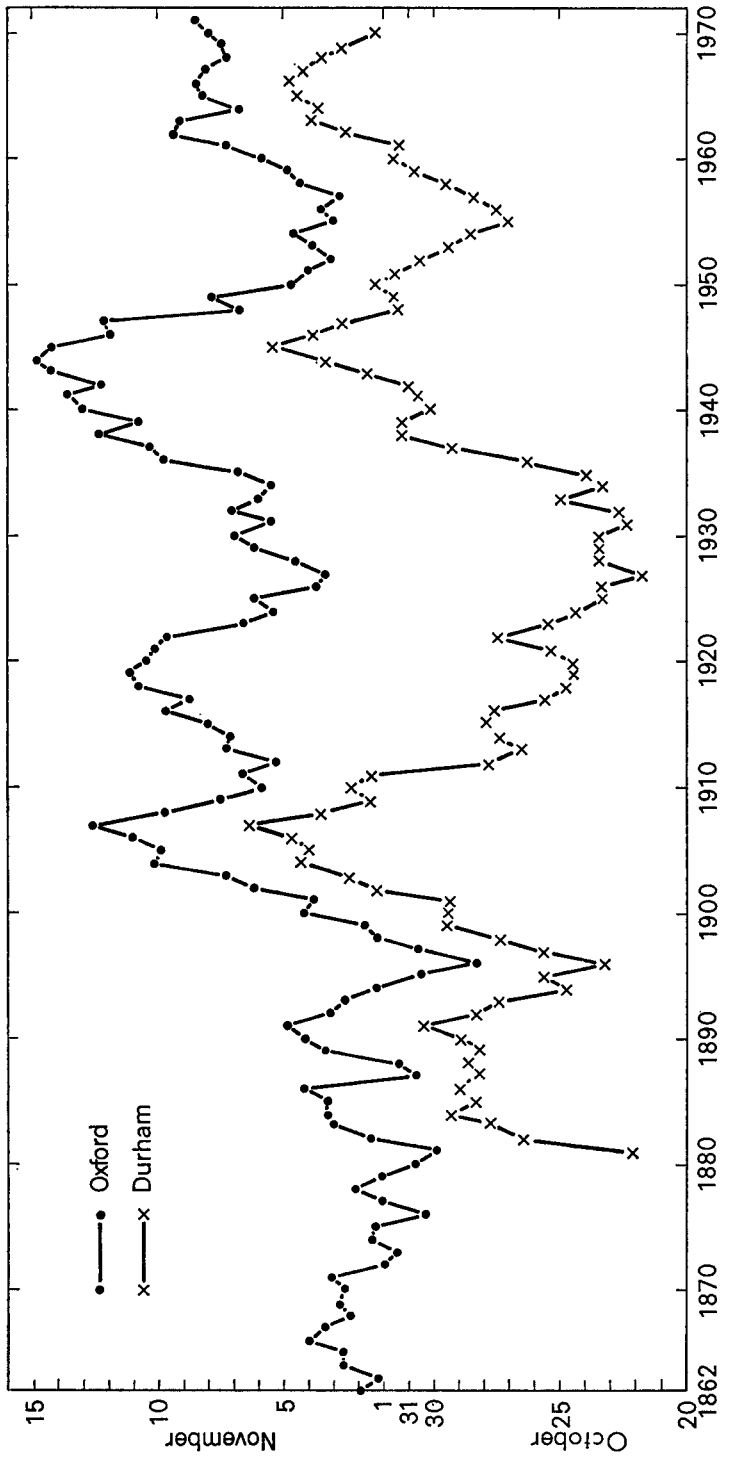

FIGURE 2—10-YEAR RUNNING MEANS OF THE DATE OF THE FIRST COLD SNAP AT OXFORD AND DURHAM
Plots refer to the 10-year period ending in the year named.

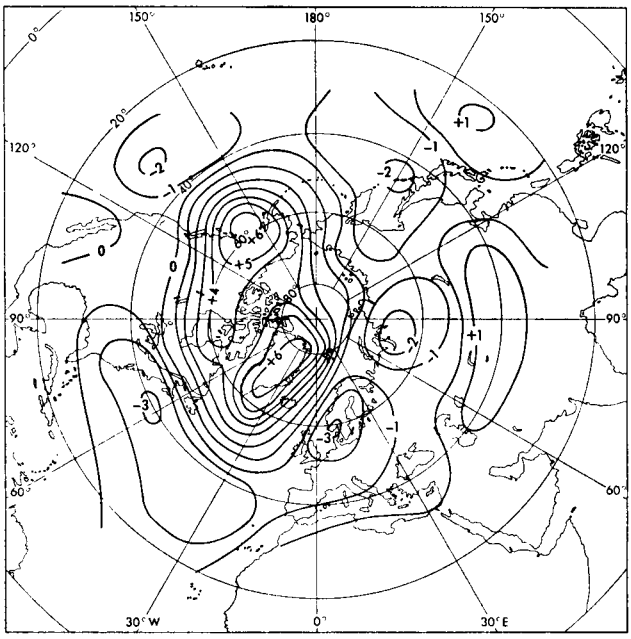

FIGURE 3—MEAN-SEA-LEVEL PRESSURE ANOMALY FOR OCTOBER 1887–96
Departures in millibars are measured with respect to the mean October values for the period 1873–1968.

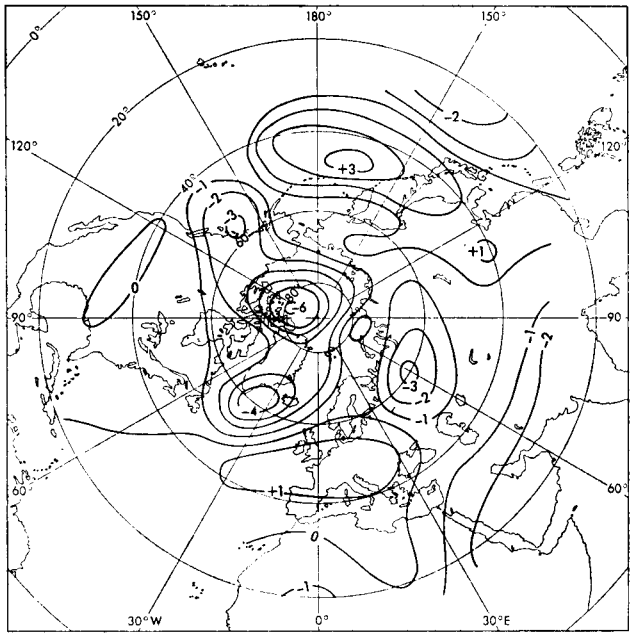

FIGURE 4—MEAN-SEA-LEVEL PRESSURE ANOMALY FOR OCTOBER 1956–65
Departures in millbars are measured with respect to the mean October values for the period 1873–1968.

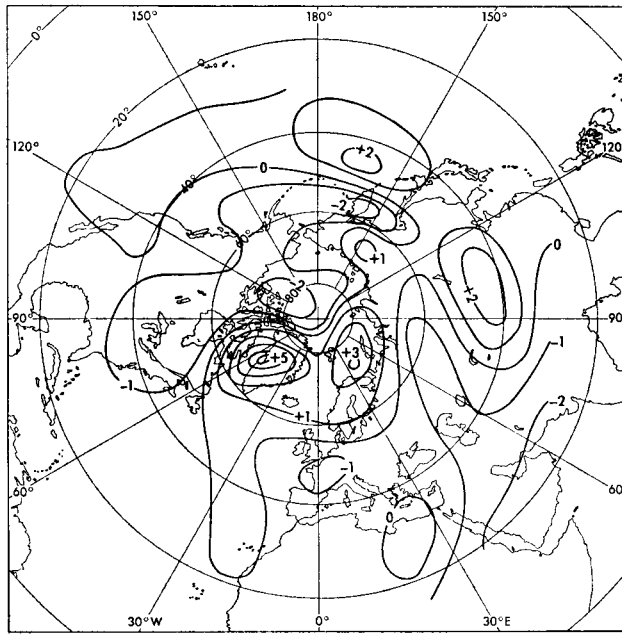

FIGURE 5—MEAN-SEA-LEVEL PRESSURE ANOMALY FOR NOVEMBER 1956–65
Departures in millibars are measured with respect to the mean November values for the period 1873–1968.

TABLE II—MEAN DATE OF THE FIRST COLD SNAP FOR THE PERIODS 'UP TO 1920' AND '1921 TO 1970'

Place	Mean date up to 1920	Number of years	Mean date 1921–70	Difference *days*
Durham	28 October	49	30 October	+2
York	2 November	43	4 November	+2
Douglas	5 November	43	5 November	0
Bidston	30 October	47	3 November	+4
Buxton	18 October	45	21 October	+3
Spurn Head	3 November	42	5 November	+2
Gorleston	4 November	48	9 November	+5
Oxford	5 November	50	8 November	+3
Cambridge	7 November	48	5 November	−2
Kew	4 November	40	7 November	+3
Cheltenham	3 November	43	4 November	+1
Ross-on-Wye	5 November	41	5 November	0
Hastings	9 November	47	13 November	+4
Southampton	12 November	50	15 November	+3
Plymouth	19 November	48	24 November	+5

WEATHER SITUATIONS ASSOCIATED WITH EARLY AND LATE DATES

Figure 6 gives the mean-sea-level pressure map averaged over the following days in October:

1908 20th	1931 18th	1948 22nd
1917 22nd	1933 22nd	1949 27th
1926 16th	1939 21st	1951 18th

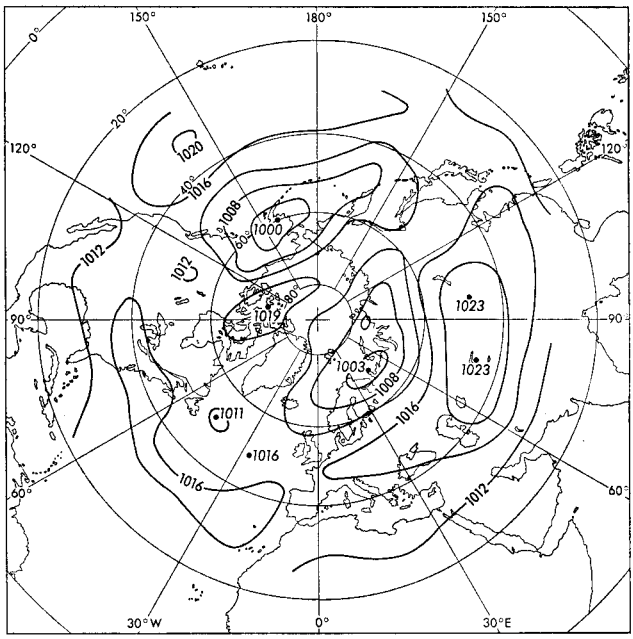

FIGURE 6—MEAN-SEA-LEVEL PRESSURE MAP FOR 'EARLY DAY −5'

Isopleths are averaged over 20 Oct. 1908, 22 Oct. 1917, 16 Oct. 1926, 18 Oct. 1931, 22 Oct. 1933, 21 Oct. 1939, 22 Oct. 1948, 27 Oct. 1949 and 18 Oct. 1951.

These dates are 5 days before the date of the first cold snap (in those particular years) at Kew, Cambridge and Nottingham. This mean chart (for day −5) shows low pressure in the southern Barents Sea, a westerly flow across the United Kingdom, a weak ridge in the Atlantic, low pressure east of Newfoundland and high pressure in the Canadian Arctic. Figure 7 shows the mean for one day later (day −4). The Newfoundland low has moved to 25°W with a trough to the Azores, the ridge is crossing the UK and high pressure has spread into northern Greenland. Figure 8 shows the mean for (day −3). The low has continued into southern Scandinavia and high pressure has spread further over Iceland with northerly winds as far as Scotland. The trough over the Azores has formed a cut-off centre. Figure 9 (day −2) shows the Azores low spreading eastwards whilst the first break of northerlies has moved into Denmark and northern Germany. Figure 10 (day −1) shows a fall of pressure over France and a north to north-east airstream over England. On this day, the maximum temperatures failed to reach 9°C. Figure 11 (day 0) shows an intensification of the system over Europe so that maximum temperatures fail to reach 9°C for the second day running.

Figure 12 gives the mean-sea-level pressure map averaged over the following days in November:

1896	17th	1914	17th	1936	14th
1899	13th	1916	11th	1954	16th
1902	12th	1932	16th	1963	16th
1907	15th				

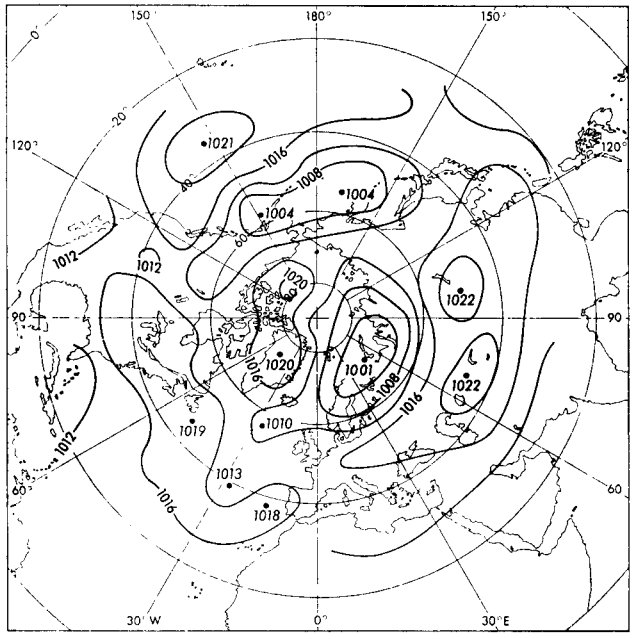

FIGURE 7—MEAN-SEA-LEVEL PRESSURE MAP FOR 'EARLY DAY —4'

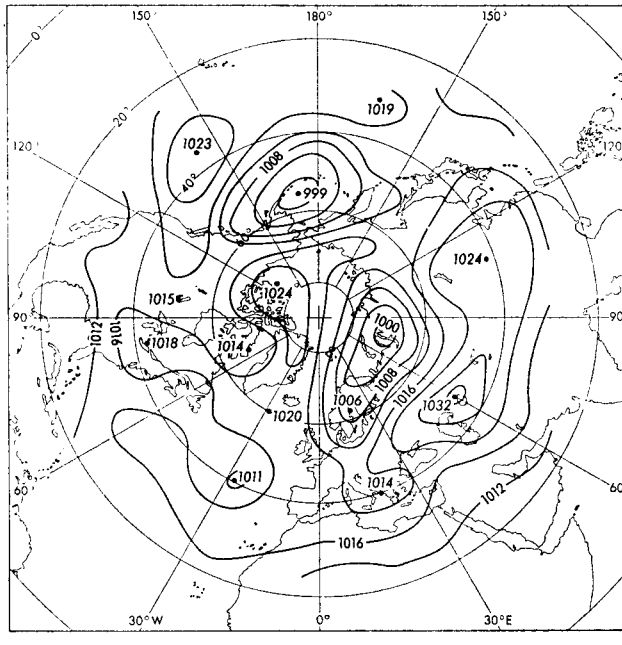

FIGURE 8—MEAN-SEA-LEVEL PRESSURE MAP FOR 'EARLY DAY —3'

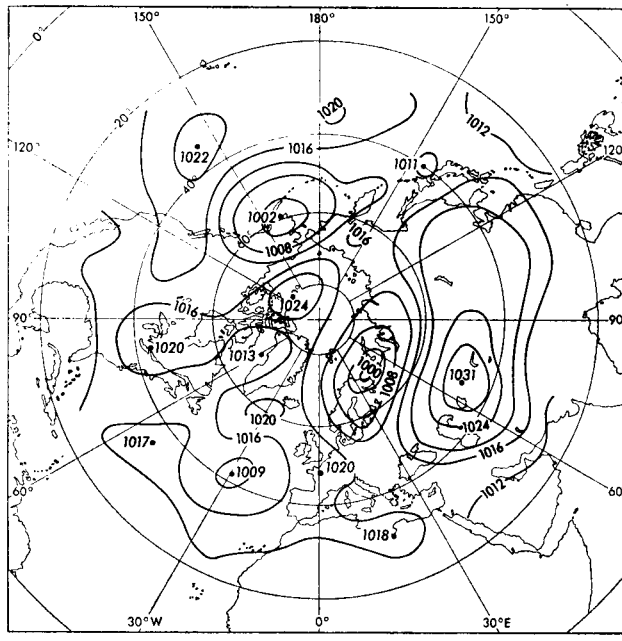

FIGURE 9—MEAN-SEA-LEVEL PRESSURE MAP FOR 'EARLY DAY —2'

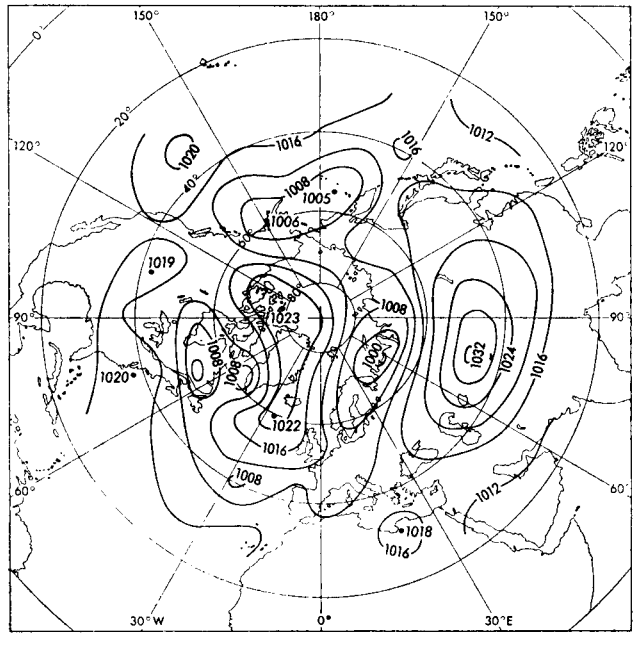

FIGURE 10—MEAN-SEA-LEVEL PRESSURE MAP FOR 'EARLY DAY —1'

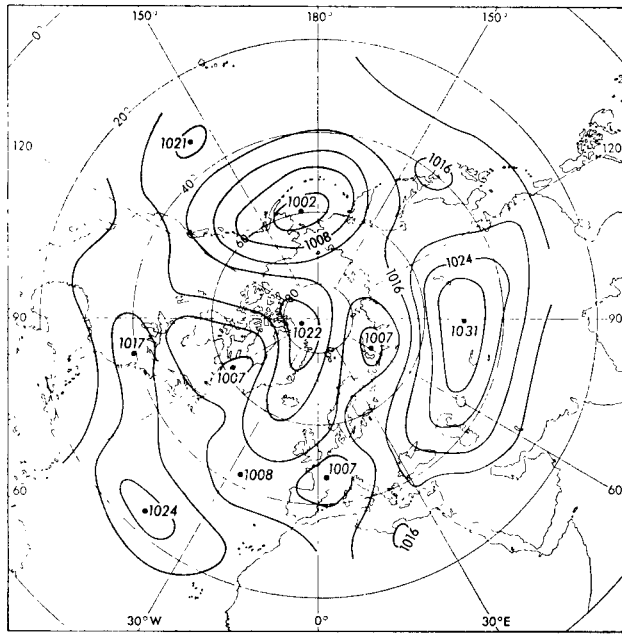

FIGURE 11—MEAN-SEA-LEVEL PRESSURE MAP FOR 'EARLY DAY 0'

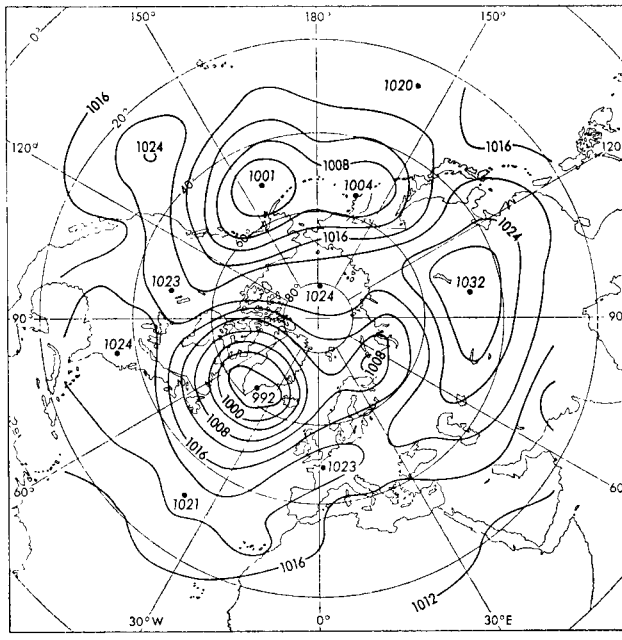

FIGURE 12—MEAN-SEA-LEVEL PRESSURE MAP FOR 'LATE DAY −5'
Isopleths are averaged over 17 Nov. 1896, 13 Nov. 1899, 12 Nov. 1902, 15 Nov. 1907, 17 Nov. 1914, 11 Nov. 1916, 16 Nov. 1932, 14 Nov. 1936, 16 Nov. 1954 and 16 Nov. 1963.

These dates are 5 days before the date of the first cold snap (in those particular years) at Kew, Cambridge and Nottingham. On (day −5), in great contrast to Figure 4, pressure is low over southern Greenland and high over France and Spain, giving a south-westerly flow over the UK. On (day −4) and (day −3) (Figures 13, 14) pressure rises slowly over Scandinavia. On (day −2) (Figure 15) the main centre of high pressure is over north-west Russia. On (day −1) (Figure 16), pressure is high over the Baltic and a cold easterly airstream has reached England. On this day the maximum temperatures failed to reach 9°C. Day 0 (Figure 17) shows an intensification of the easterly flow so that the maximum temperatures again failed to reach 9°C.

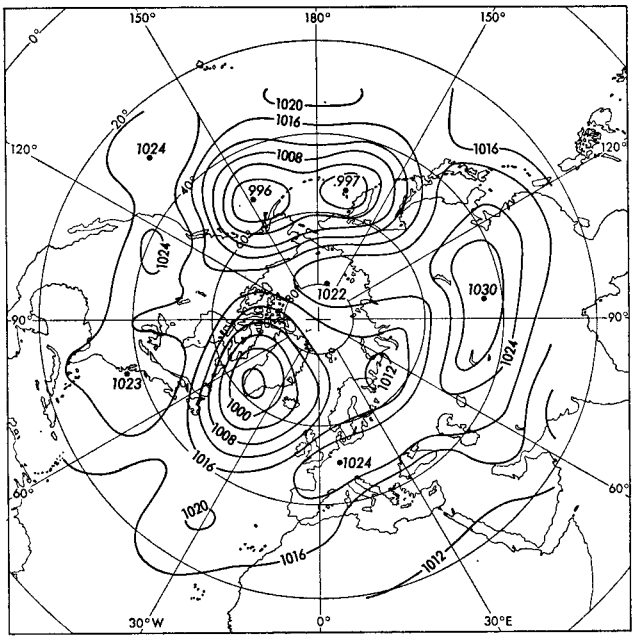

FIGURE 13—MEAN-SEA-LEVEL PRESSURE MAP FOR 'LATE DAY −4'

The bimodal nature of the distributions at a large number of stations probably arises because the annual decline of temperature is such that with high pressure over Iceland and northerlies over the UK, maximum temperatures in those northerlies will fail to reach 9°C over the UK by about the third or fourth week of October. On the other hand, with low pressure over Greenland/Iceland, the maximum temperatures in the easterly/south-easterly airstreams that may occur over England continue to reach 9°C until about the second week of November.

Variation of first cold snap with altitude

On any occasion, the first cold snap advances southwards over the UK in a series of surges. For example, in 1970 the first surge occurred on 21 October, bringing the first cold snap to most of northern England and the Midlands. The second surge occurred between 12 and 15 November, bringing the first cold

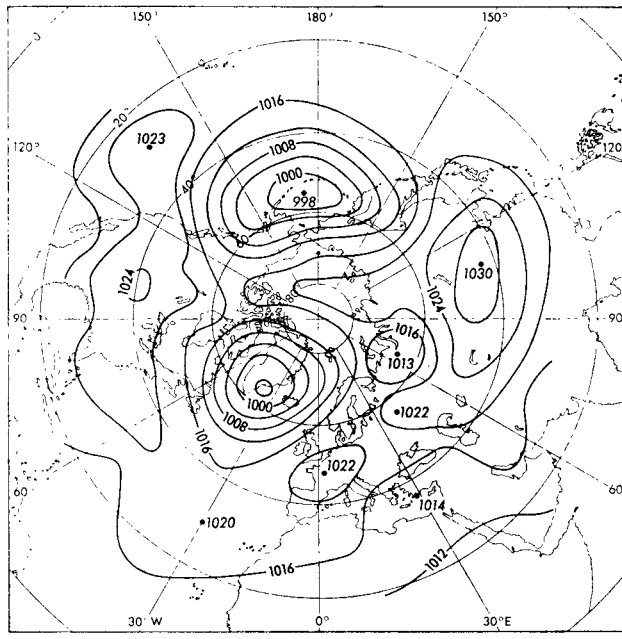

FIGURE 14—MEAN-SEA-LEVEL PRESSURE MAP FOR 'LATE DAY —3'

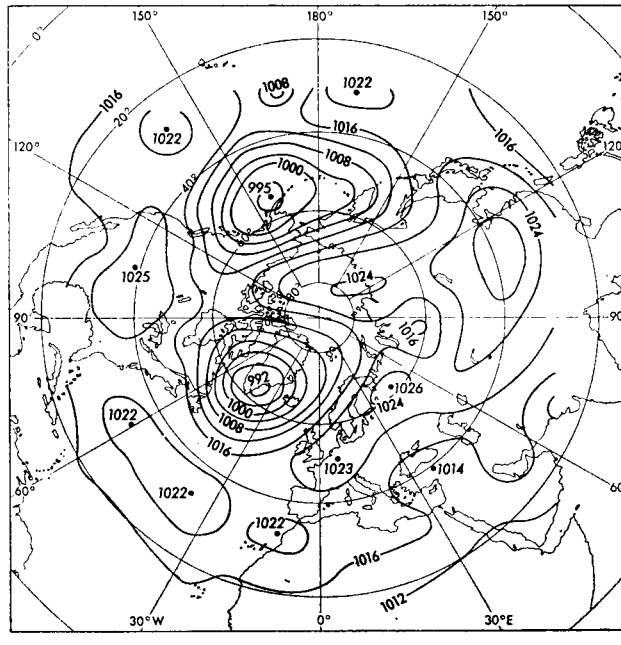

FIGURE 15—MEAN-SEA-LEVEL PRESSURE MAP FOR 'LATE DAY —2'

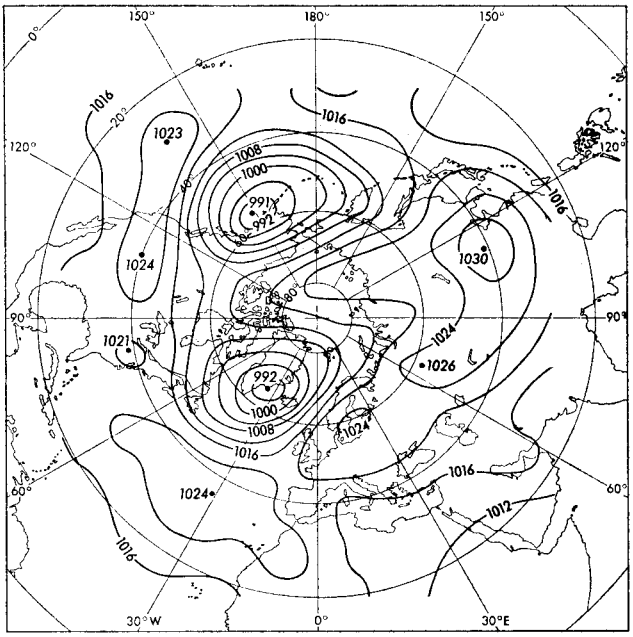

FIGURE 16—MEAN-SEA-LEVEL PRESSURE MAP FOR 'LATE DAY —1'

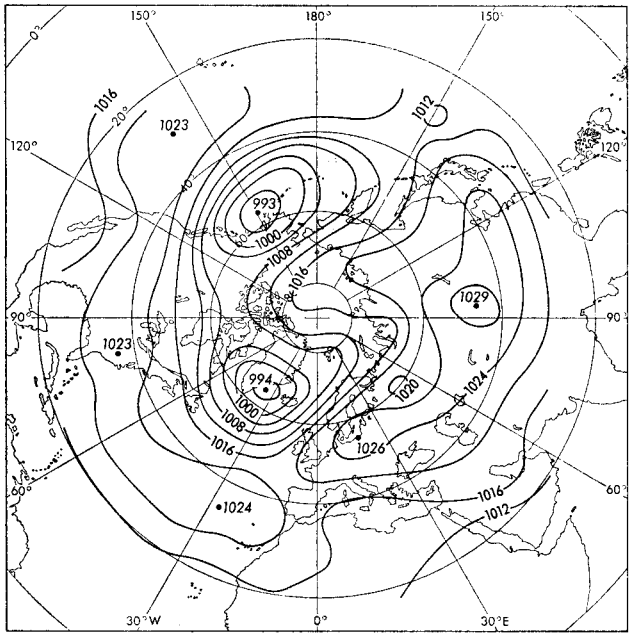

FIGURE 17—MEAN-SEA-LEVEL PRESSURE MAP FOR 'LATE DAY 0'

snap to the remainder of north-west England, all eastern England and further parts of southern England and South Wales. The third surge occurred on 9 December, bringing the first cold snap to the remainder of southern England and South Wales except for extreme south-west Cornwall.

The higher the altitude of a station the greater the chance of it being affected by the first surge. In the example just given Shaftesbury, at an altitude of 220 m, experienced its first cold snap in the first surge whereas Bath and Reading, at 26 m and 47 m respectively, did not. Averaged over a number of years, the mean date will occur earlier at a higher-level station than at a lower-level station nearby.

By comparing nearby stations at different altitudes, it is possible to form an estimate of how much earlier the first cold snap occurs as altitude increases. Table III gives the difference in days between the mean date of the first cold snap at neighbouring stations at different altitudes:

TABLE III—DIFFERENCE IN DAYS BETWEEN THE MEAN DATES OF THE FIRST COLD SNAP OF NEIGHBOURING PAIRS OF STATIONS AT DIFFERENT ALTITUDES

Stations	Height difference *metres*	Days difference	Average per day *metres*
Bradford and York	116	6·96	16·7
Buxton and Nottingham	248	14·48	17·1
Birmingham and (Oxford + Nottingham)	120	6·61	18·1
Rothamsted and Kew	108	6·34	17·0
Shaftesbury and (Bath + Southampton)	187	9·77	19·1

This table gives an average of 17·5 metres per day*. This value compared with that deduced by using a change of 3·5 K from October to November in the mean temperature for central England and a standard-atmosphere lapse rate of 6·5 K/km, which gives a value of 17·65 metres per day.

Using this correction of one day for every 17·5 metres of altitude, Figure 18 gives isopleths of the mean date (reduced to sea level), based on some 40 stations in England and Wales over the period 1921–70. North of the Thames Valley, the mean (sea level) date is between 5 and 10 November, but north-east England (Northumberland, Durham and Yorkshire) have a mean date before 5 November. Only the south coast, south-west England and the south-west corner of Wales have a date after 15 November.

Figures 19 and 20 give isopleths of the third earliest and third latest dates (reduced to sea level) in the 50-year period 1921–70. About 90 per cent of years fall within these dates, and for most places they are about 15 days before and after the mean date, except in south-west England where the range increases to near 30 days.

* Text printed as received. Table III in fact yields a value of 17·6 m/day and using this value might have slightly modified Figure 18 (Editor).

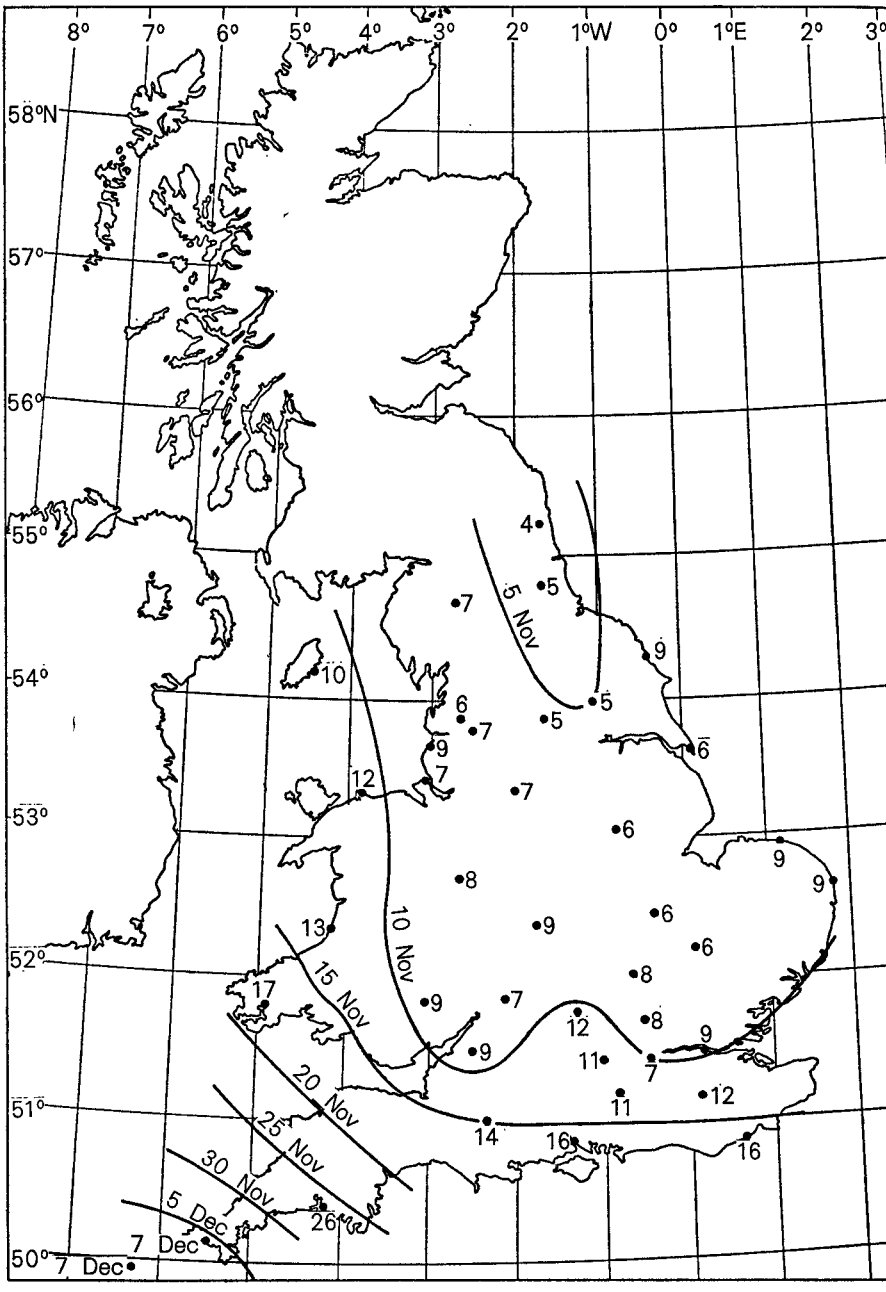

FIGURE 18—MEAN DATE OF FIRST COLD SNAP OF AUTUMN (REDUCED TO SEA LEVEL) IN THE PERIOD 1921–70

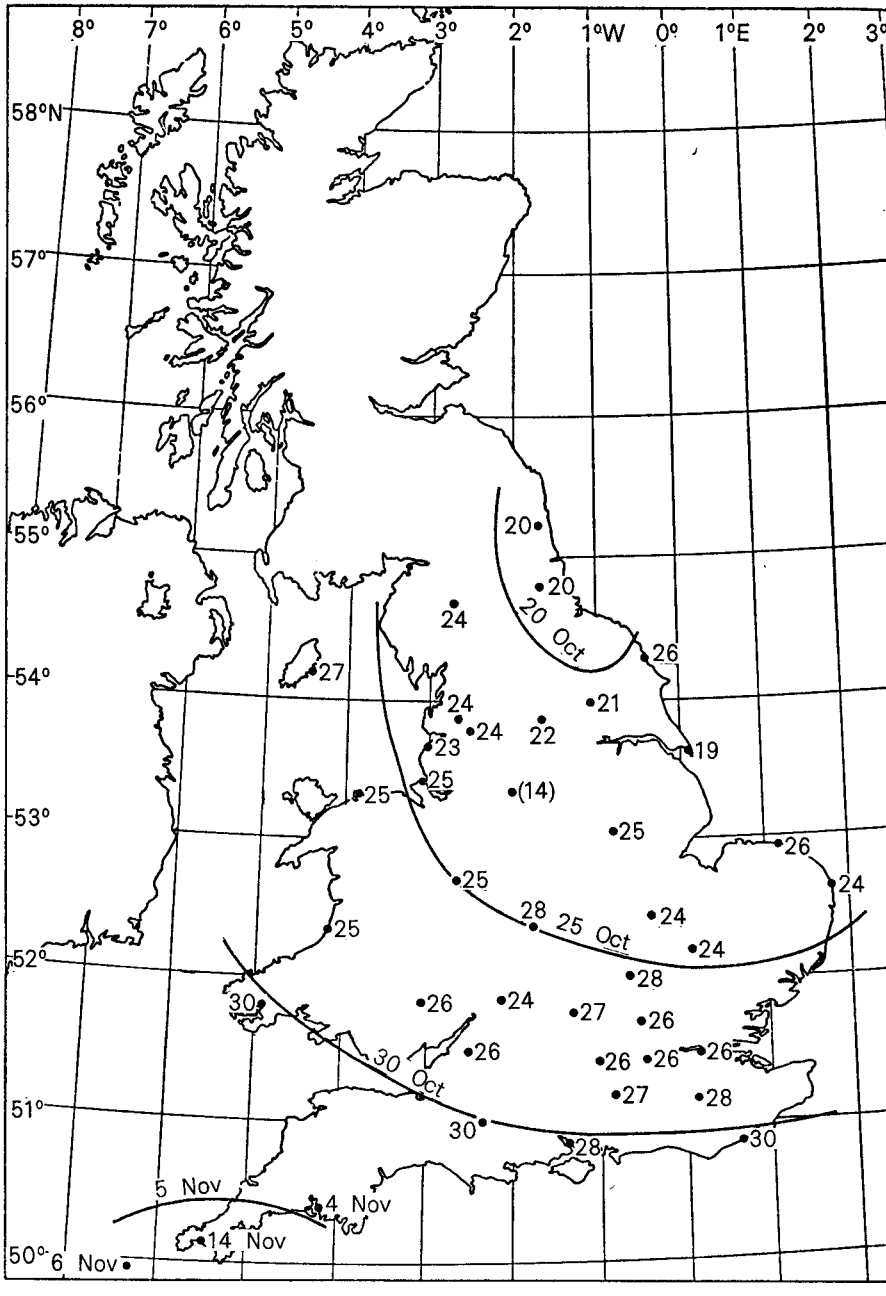

FIGURE 19—MEAN THIRD EARLIEST DATE OF FIRST COLD SNAP OF AUTUMN (REDUCED TO SEA LEVEL) IN THE PERIOD 1921–70

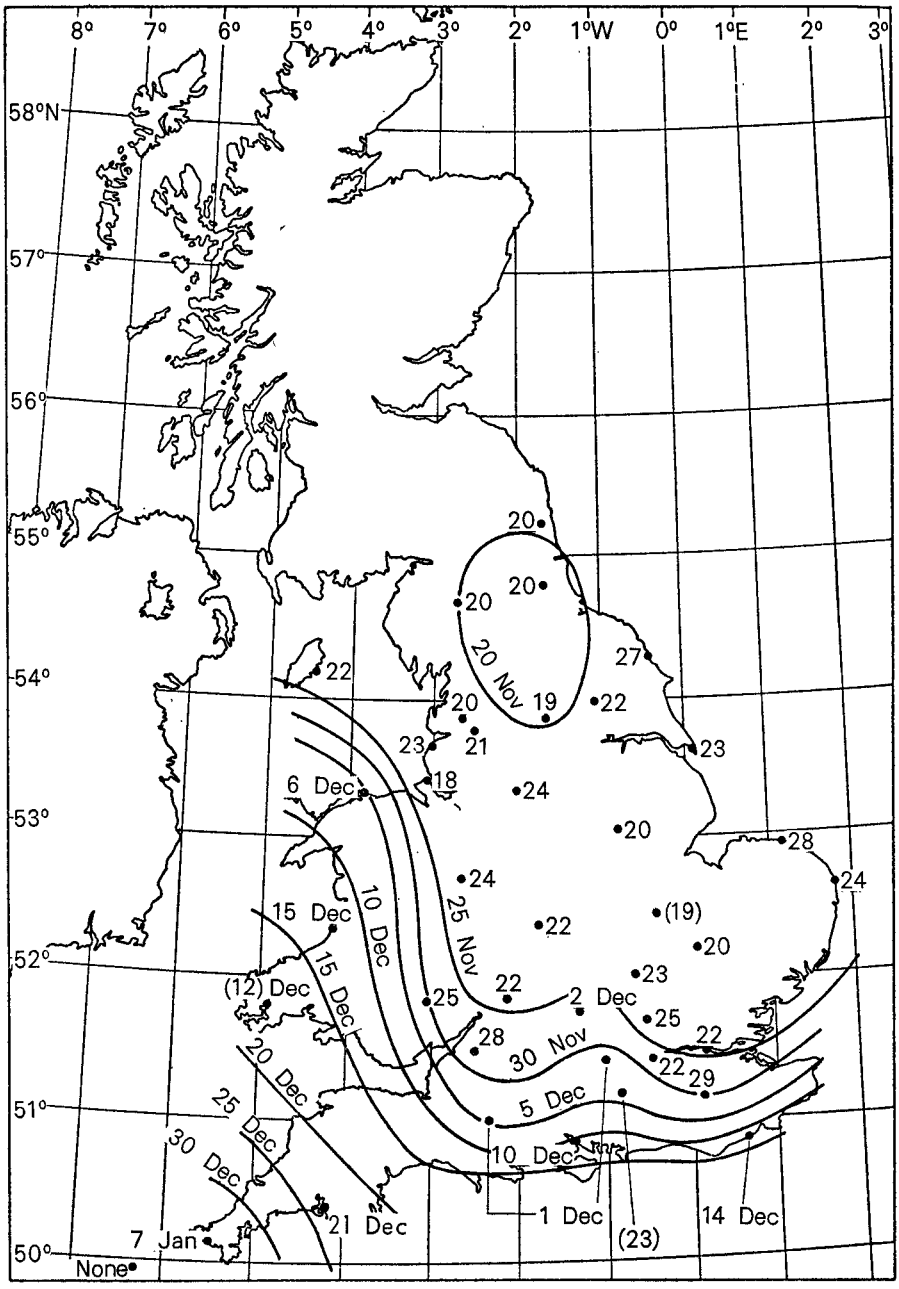

FIGURE 20—MEAN THIRD LATEST DATE OF FIRST COLD SNAP OF AUTUMN (REDUCED TO SEA LEVEL) IN THE PERIOD 1921–70

FORECASTING THE DATE

Over the four-year period 1970 to 1973, an attempt was made to forecast the date of the first cold snap at Oxford by using the methods of long-range forecasting that were used in making some experimental forecasts for autumn based on certain aspects of the weather during the summer. These forecasts were made on 1 September with the following results:

	Forecast	Actual
1970	9 November	13 November
1971	7 November	10 November
1972	14 November	16 November
1973	13 November	21 November

For the 50-year period 1921–70, average dates fall between 5 and 9 November, late dates between 10 and 14 November, and very late dates after 15 November. The predictions were for 2 average and 2 late dates against actuals of 2 late and 2 very late dates. In practice, further work would have to be done to update the forecasts on (say) 1 and 16 October and to make forecasts of the event 24 or 48 hours ahead. Methods of doing this have yet to be developed.

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BROOKS, C. E. P. and CARRUTHERS, N. 1953 Handbook of statistical methods in meteorology. London, HMSO.

DAVIS, N. E. 1972 Classified central England temperatures and England and Wales rainfall. *Met Mag*, **101**, pp. 205–217.

REVIEWS

Meteorology and Climatology (*Volume 1, Geophysics Series*), I. P. Danilova and A. P. Kapitsa (Scientific Editors). 235 mm × 165 mm, pp. i + 223, G. K. Hall & Co., 70 Lincoln Street, Boston, Mass., USA, 1975. Price: $29·00.

The Geophysical Department of VINITI, the All-Union Institute for Scientific and Technical Information, has planned to publish about every two years a set of volumes containing reviews on various aspects of Geophysics, Oceanology, Meteorology and Climatology, Physics of the Earth, Glaciology, Geomagnetism and the Upper Atmosphere. This volume is the first in the series on Meteorology and Climatology and the original Russian text was published in Moscow in 1971. It contains six major articles written by leading scientists and accordingly presents authoritative views on the state of these subjects both within and outside the USSR based on studies of world literature up to about 1970.

In the first section A.Kh. Khrgian briefly discusses recent developments in Physical Meteorology under the general headings of Textbooks on Meteorology,

Radiosondes, Dynamics and Macrophysics of Clouds, and Atmospheric Electricity. Although interesting and containing a useful large bibliography a more detailed and comprehensive treatment would have been welcomed in view of the large world-wide research effort devoted to different aspects of this subject in recent years. The second section written by K. Ya. Kondrat'yev on Satellite Meteorology contains a broad and quite detailed survey of the subject including Instruments carried by Weather Satellites, Interpretation of Television and Infra-red Pictures, the Earth's Thermal Budget, and Remote Sounding, backed by about 300 references. Even then the author notes that he has only been able to discuss the most important results in current work and the scientific literature actually discusses a much broader range of problems. The next section by the late B. L. Dzerdzeyevskiy is entitled 'Basic Problems of Climate Formation, Variability of Climate Regimes and Atmospheric–solar Relations'. This covers an enormous field and the author, again using a large number of references, has attempted to produce a comprehensive coverage. Consequently subjects which have attracted very considerable effort such as atmospheric pollution and weather modification are dealt with in a few pages and the impression is that the article will be of most use to workers in this general area who mostly need guidance to papers on recent work rather than an overall assessment of the subject. The same kind of comments may also be made about the next article on Agricultural Meteorology and Climatology by Yu. I. Chirkov and V. A. Shablevskaya. Here, however, the subject matter is more limited and specialized and no doubt the description of the extensive USSR effort in this important field will be of considerable interest to workers in other countries. The fifth section 'Photochemical Processes involved in the Generation of the Ozonosphere' by I. M. Kravchenko is rather different in concept, giving with comparatively few references an interesting account of the physical basis of this subject. Unfortunately it was written just before it became widely accepted that several minor constituents, particularly nitrogen oxides, considerably modify the ozone photochemistry and the large-scale studies of possible stratospheric ozone depletion due to aircraft operations and chemical releases at the surface were started. The later developments are certainly well known to the USSR workers and the apparent limitations of this article are of course a penalty of the time interval between its preparation and its general availability in the English language. The final article 'Climatic Existence Conditions for Glaciers and the Shaping of Glacial Climates' by A. N. Krenke deals comprehensively with most aspects of this subject, contains about 200 references, and appears to be a very useful contribution for specialists in this field.

In summary this volume although somewhat uneven in its treatment of the various subjects presents a valuable collection of articles and provides connected accounts of achievements both within and outside the USSR. In general its most important feature is the direction within the different articles to their sources of information and it seems likely that its main value will be in this aspect rather than in an attempt to obtain an assessment from it of the current status of a subject. Its application to current studies suffers considerably from the delay since its first appearance in the USSR but it and subsequent numbers in the series should certainly be acquired by libraries for the use of specialists and students attempting to gain an overall view of world-wide efforts in their field.

R. J. MURGATROYD

Noctilucent clouds, by V. A. Bronshten and N. I. Grishin. 240 mm × 170 mm, pp. v + 237, *illus.* (translated from the Russian by Israel Program for Scientific Translations, Jerusalem), John Wiley and Sons Ltd, Baffins Lane, Chichester, Sussex, 1976. Price: £13·20.

It will not be necessary to remind meteorologists that noctilucent clouds are those curiously high clouds (at approximately 80 km altitude) that can be seen from Scotland and other high-latitude places on many midsummer nights. First recognized as unusual in 1885 (the Krakatoa eruption was in 1883 and may or may not have caused particularly bright clouds to appear in subsequent years), the morphology and nature of the clouds is not yet clear. This book surveys in great detail nearly 70 years of observation, analysis and speculation. Much of the observational work has been carried out in the USSR with the inspiration, and under the supervision of, the authors. Noctilucent cloud studies here in the British Isles were for many years co-ordinated by the late James Paton and it is welcome news that they are to continue, with the guidance of Dr McIntosh of the Meteorology Department, Edinburgh University.

The volume under review continues the successful series of translations by the Israel Program for Scientific Translations. However, it has to be said that the English text appears not to have been read through by a meteorologist, or an upper-atmosphere physicist, to make the translation a little freer, perhaps a little more colloquial. It would then read better and some mistakes might have been avoided. For example, Jesse (1896) claimed an uncertainty of ±0·009 km for the mean of his height measurements, not 0·09; the legend to Figure 6 should refer to 'smoothed' rather than to 'flattened' curves; one has 'square degrees' rather than 'quadratic degrees' (the Russian word is *kvadratnyy*); aluminium is 'evaporated' not 'pulverized' (from *pul'verizatsiya*) in shadowing specimens for electron microscopy; Venus occults the star Regulus, Regulus does not cover Venus. But none of these does more than pull the reader up by the use of inappropriate words. In a few places the meaning is changed in the translation; e.g. *'ili zhe imelis neskol'ko otdel'nikh oblachnikh polei, razdelennikh promezhutkami'* seems to me to be 'or else had several separate cloud areas, with intervening gaps' rather than 'or compressed cloud fields separated by intervals'; *'togda kak do polynochi'* is surely 'while up to midnight' not 'while after midnight'?

Almost six hundred references are listed in the bibliography and the presence of these, tied to critical discussion in the text, alone almost fully justifies the efforts of Bronshten and Grishin. Were I to have been involved in the translation, I would have improved the book by compiling author and subject indexes; without them, it is difficult to refer quickly to a particular topic.

There is now increasing interest in the behaviour of the upper atmosphere and in relationships between solar activity and climate or weather. Noctilucent clouds provide a visible indicator of conditions in the high atmosphere; their study will grow in importance and popularity in the next few years. The research worker and the student, the meteorologist and the layman, can all rely on this textbook keeping its place for many years, as it has for six years already in the Russian text.

M. GADSDEN

NOTES AND NEWS

Election of Dr B. J. Mason to the Presidency of the Institute of Physics

Dr B. J. Mason, C.B., F.R.S., the Director-General of the Meteorological Office, has been elected President of the Institute of Physics for a two-year term beginning on 1 October 1976. He succeeds Professor Sir Brian Pippard. The Institute has more than 16 000 members, holds about 60 major meetings each year, publishes journals to the value of more than £1 million per annum, and is responsible for the Fulmer Research Institute which undertakes commissioned research.

Symposium on Meteorological Services (other than weather forecasting) for Water Management

A Symposium on 'Meteorological Services (other than weather forecasting) for Water Management' was held at the Meteorological Office College, Shinfield Park, Reading on 24 March 1976. The Symposium was opened by Dr B. J. Mason, C.B., F.R.S., Director-General, Meteorological Office and was chaired by Mr J. K. Bannon, I.S.O., Director of Services. An invited audience represented many organizations interested in water, such as the Regional Water Authorities of England and Wales, the Central Water Planning Unit, the Water Data Unit, the Hydraulics Research Unit, the Water Research Centre, the Institute of Hydrology, the Greater London Council, the Department of the Environment, the Ministry of Agriculture, Fisheries and Food and a number of engineering firms.

There were four papers, namely 'Handling hydrometeorological data' by R. J. Shearman, 'Answering enquiries on rainfall, evaporation and soil moisture deficit' by B. G. Wales-Smith, 'Rainfall analysis and snow studies for drainage design' by J. F. Keers and 'Measurement of meteorological elements of interest to water management' by Dr T. W. Harrold.

A slightly shortened version of the Shinfield Park Symposium was held at Edinburgh on 13 May 1976 and attended by nearly 50 hydrologists and engineers. Mr W. G. Harper, Superintendent, Meteorological Office, Edinburgh chaired the Symposium and Mr J. F. Keers and Mr B. G. Wales-Smith covered the work which was dealt with in the first three talks given at the Shinfield Park Symposium in March 1976.

At both symposia each talk was followed by a lively and informative discussion. It was clear that many participants had not hitherto been aware of the variety of hydrometeorological services available from the Meteorological Office. The flow of information was two-way, and the Office found out a good deal about the problems and requirements of the various organizations which have an interest in operational hydrology and engineering.

The spelling of 'program'

Some readers have expressed concern that the *Meteorological Magazine* should have adopted what they describe as the American way of spelling as 'program' the word that they are generally used to seeing spelt in British publications—except perhaps when it refers to computers—as 'programme'. This shorter spelling, however, is not exclusively modern American in origin but is also traditional English and was employed from the first recorded use of the word in the early 17th century until a French way of spelling it began to be adopted in the 19th; some leading writers, e.g. Scott, Carlyle, Browning and Shaw, resolutely maintained the old spelling.

'Program' is consistent in its spelling with all other English words incorporating the same Greek root, e.g. telegram, monogram, diagram etc., and is the first and preferred spelling in the 'Shorter Oxford English Dictionary'.

EDITOR

OBITUARY

It is with regret that we have to record the death on 2 June 1976 of Mr A. W. E. Barber, Higher Scientific Officer, Met.O.7.

THE METEOROLOGICAL MAGAZINE

VOL. 105 NO. 1251 OCTOBER 1976

CONTENTS

Page

Precipitation climatology of the Tehran area. A. Khalili 293

The first cold snap of autumn. N. E. Davis 306

Reviews

Meteorology and Climatology (*Volume 1, Geophysics Series*). I. P. Danilova and A. P. Kapitsa (Scientific Editors). *R. J. Murgatroyd* 324

Noctilucent clouds. V. A. Bronshten and N. I. Grishin. *M. Gadsden* 326

Notes and news

Election of Dr B. J. Mason to the Presidency of the Institute of Physics 327

Symposium on Meteorological Services (other than weather forecasting) for Water Management 327

The spelling of 'program' 328

Obituary 328

NOTICES

It is requested that all books for review and communications for the Editor be addressed to the Director-General, Meteorological Office, London Road, Bracknell, Berkshire, RG12 2SZ, and marked 'For Meteorological Magazine'.

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